Final Report

A project under the Canada
New Brunswick Conservation
and Renewable Energy
Demonstration Program

WOOD RESIDUE BOILER
BETH SHALOM
ARTHURETTE, N.B.

March, 1985

CREDA Project #2046

Prepared by:

Paul Gregoire
Beth Shalom

and

N.B. Energy Secretariat

Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

The Conservation and Renewable Energy Demonstration Program Program is administered in New Brunswick by the Energy Secretariat and managed jointly with Energy, Mines and Resources Canada. The Program is designed to help demonstrate promising conservation and renewable energy technologies, to develop public awareness and understanding of these technologies, and to create employment in new or existing industries.

Through over 100 demonstration projects in New Brunswick, a wide variety of conservation and renewable energy technologies have proven to be technically sound and economically attractive. These demonstration projects should now provide a catalyst for commercialization and lead to widespread adoption of many of these proven technologies.

This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

Conservation & Renewable
Energy Division
Energy Secretariat
P.O. Box 6000
Fredericton, N.B.
E3B 5H1
(506) 453-3897

Programme Canada/Nouveau-Brunswick de démonstration des économies d'énergie et des énergies renouvelables

Le Programme de démonstration des économies d'énergie et des énergies renouvelables est administré au Nouveau-Brunswick par le Secrétariat à l'énergie, en collaboration avec Energie, Mines et Ressources Canada. Ce programme tente d'abord de vérifier la fiabilité des techniques de conservation d'énergie, d'accroître la sensibilité du public envers ces techniques et, enfin, de favoriser la création d'emplois au sein des industries nouvelles ou déjà existantes.

Un grand nombre de projets de démonstration se sont avérés à la fois techniquement réalisables et économiquement attrayants.

Le succès ainsi rencontré encourage la commercialisation des procédés les plus accessibles. Cela entraînerait certes l'adoption d'un grand nombre de ces techniques par les propriétaires de domiciles et par l'industrie privée.

Ce rapport final est basé sur un projet qui a reçu une aide financière du Programme de démonstration. Pour de plus amples renseignements, communiquez avec la:

Division des économies d'énergie
et des énergies renouvelables
Secrétariat à l'énergie
C.P. 6000
Fredericton, N.-B.
E3B 5H1
(506) 453-3897

D I S C L A I M E R

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D E N I D E R E S P O N S A B I L I T E

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1.0 EXECUTIVE SUMMARY

In the fall of 1982 Beth Shalom Inc. obtained funding assistance from the New Brunswick Energy Secretariat to demonstrate the feasibility and applicability of installing three (3) sawdust/woodchip fired boilers . The $68,500 grant was provided under the Canada-New Brunswick Conservation and Renewable Energy Demonstration Program, a program to encourage the use of renewable energy by stimulating the development of appropriate systems consuming these different sources of energy.

For economic reasons Beth Shalom had to consider alternate energy systems to replace its existing oil boilers if it were to continue operating its Special Care Home facility. During the 1983-1984 heating season the new woodchip heating system proved effective in providing the heat required by the three buildings without having to resort to the oil back-up system.

An energy saving of 75% was realized in the first heating season alone. The simple payback for this project is 8.5 years making this type of retrofit very economical for other small or large institutions. The total environmental impact of consuming this fuel source has advantages that few energy sources have.

1.0 SOMMAIRE RECOMMANDATION

A l'automne 1982, Beth Shalom Inc. obtenait une subvention de 65 000 $ du Secrétariat à l'énergie du Nouveau-Brunswick pour démontrer la faisabilité et les possibilités d'application de trois chaudières à sciure/copeaux de bois. Cette subvention était financée conjointement en vertu du Programme Canada/Nouveau-Brunswick de démonstration des économies d'énergie et des énergies renouvelables, un programme visant à encourager l'utilisation des énergies renouvelables pour stimuler la mise en place de systèmes basés sur la consommation de différentes sources d'énergie.

Pour des raisons économiques, Beth Shalom devait envisager l'installation de systèmes de rechange pour remplacer ses chaudières existantes au mazout pour pouvoir continuer d'exploiter son foyer de soins spéciaux. Pendant la saison de chauffage 1983 - 1984, le nouveau système de chauffage aux copeaux de bois s'est avéré efficace en fournissant toute la chaleur requise aux trois bâtiments sans avoir à utiliser le système d'appoint au mazout.

La première saison de chaufffage à elle seule a permis des économies d'énergie de 75 %. Le recouvrement pour ce projet sera de 8,5 ans, ce qui prouve que ce genre de rénovations est très économique pour d'autres établissements de faibles ou de grandes dimensions. Les répercussions écologiques totales de la consommation de ce genre de combustible présentent des avantages que peu de sources énergétiques peuvent démontrer.

2.0 INTRODUCTION

2.1 Brief History of Beth Shalom

Beth Shalom Inc. is a non-profit, non-denominational, charitable organization governed by a fifteen member Board of Directors, dedicated to the goal of providing a permanent home to mentally handicapped adults.

Beth Shalom is located in Arthurette, N.B., a village on the eastern side of the Tobique River halfway between Perth-Andover and Plaster Rock. The home consists of four masonary buildings, each averaging 12m (40 ft.) in width by 33.5m (110 ft.) in length and 7.6m (25 ft.) in height. All four buildings are within 23m (75 ft.) of one another. The home is situated on 148ha (365 acres) of land, of which approximately 121ha (300 acres) is woodland.

2.2 Need for Alternate Heating System

As a non-profit charitable organization, Beth Shalom depends greatly upon the generosity of its benefactors for its survival. Sources of revenue were adequate for the proper functioning of the home but efforts had to be made to reduce the operating budget, of which sixty-five percent (65%) was spent on oil. At this rate the budget would have been completely eroded within two years by the increasing oil costs. The frequent oil price increments jeopardized the home's existence; thus, the Board of Directors investigated alternate energy sources to secure the home's stability and longevity.

Several possibilities were carefully studied: retrofitting, complete insulation of the buildings, thermopane windows, etc. However, these methods proved too costly and Beth Shalom would still have been dependent on oil. Modern oil boilers were examined but the initial investment was prohibitive; besides, oil would still have been a major factor in depleting yearly income.

Replacing the oil furnaces with either gas or electricity would have required considerable investement and the rising prices of both gas and electricity would have likewise eroded Beth Shalom's income. To survive, Beth Shalom would have to depend on economical renewable resources. Consequently, the Board of Directors chose a system which would utilize residual woodwaste products - sawdust and woodchips. This alternate fuel source proved to be the best for Beth Shalom because of its abundance, economy and availability. The Board had now decided on a central heating unit to supply heat to three buildings, with the boilers and storage area located in a vacant building.

3.0 DESCRIPTION OF DEMONSTRATION

3.1 Boilers

The heating plant at Beth Shalom includes three hot water boilers, each one rated at 400,000 BTU/h. The boilers rest on a two-foot base compartment, the boiler itself measuring about 1.3m (5 ft) in height by 0.6m (2 ft) in width and 0.9m (3 ft) in length. Two burners are attached to the front side of the base, and are equipped with detachable hoppers about 0.9m (3 ft) high by 0.9m (3 ft) wide having an individual capacity of approximately 102kg (225-250 lb) of wood residue. With the hoppers on the burners each unit is about 2.4m (8 ft) wide.

Each of the three burners is fitted with two hoppers but it is not necessary to have fuel in both hoppers for the boiler to operate. For example, in intensely cold weather, all three boilers operate with the six hoppers providing the fuel. In mild weather only one boiler fed from one hopper is necessary. The system's versatility makes it practical to operate depending on weather conditions.

The burners are simply constructed with a primary hopper and a double grate (See Figure 1). The grate is controlled by a timer which can be set to shake the grate at any time interval (varying from one minute to twenty-four hours), depending, of course, on the combustion conditions of the fuel. Hoppers being located on top of the burners or primary hoppers enable the fuel to fall onto the grate by gravity, beginning the first process of

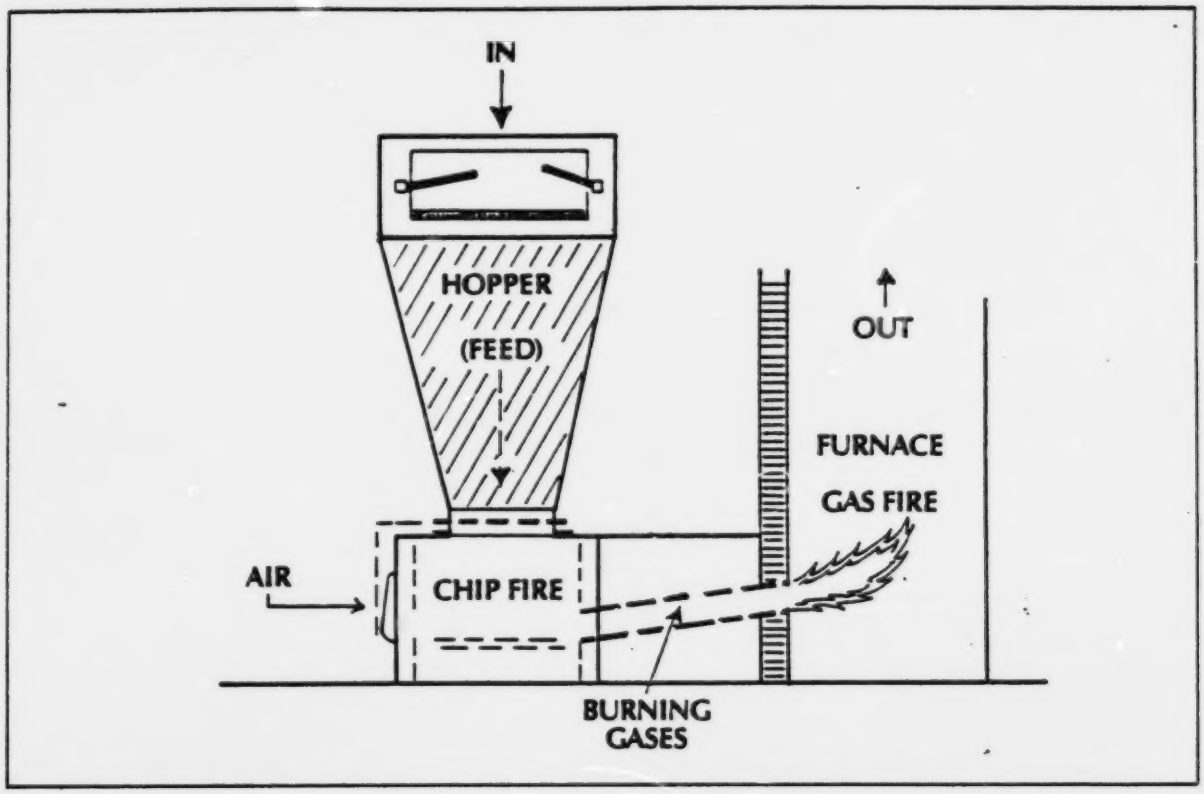

Figure 1 - Schematic of Woodchip Boiler

combustion.

On the bottom side of the burners, an ash removal door allows for the easy removal of the ashes. The entire burner weighing about 91kg (200 lb) is firmly attached to the base of the boiler by a solid steel hinge rod and locked firmly into place by an adjustable catch, forming an airtight closure. For proper maintenance of the boiler's base, the burners can be completely opened conveniently to remove the accumulated ashes within this base.

Each boiler is equipped with the necessary instruments required to monitor pressure, temperature, etc. Automatic draft controls regulate the firing rate of the burners. Circulating pumps governed by aquastats circulate the boiler water at given temperatures.

3.2 **Woodchip Handling System**

A major drawback to the system was discovered during the first few months of the heating season. The existing hoppers attached to the boilers lacked the capacity required to feed the fire for more than 8 hours. This resulted in many sleepless nights for the operator, during cold days, as he had to refill the hoppers every 5 - 6 hours. The boilers required constant attention to ensure that the hoppers were adequately filled. Also, the filling of the hoppers was done manually by means of a shovel, wheel barrow and small portable conveyor. Therefore, keeping the system going became a worrysome and labour intensive operation.

To resolve this problem it was decided to increase the capacity of the hoppers and to automate the system. Three 1.2m x 2.4m x 1.2m (4' X 8' X 4') boxes were constructed on the second floor directly over the boilers. Each box contains two small hoppers that feed directly into the two hoppers attached to each boiler located directly below (see figure 2). The new hoppers essentially increased the available capacity for each boiler from 113kg (250 lbs) to 408kg (900 lbs) to each individual hopper. This in essence triples the capacity of the hoppers.

The new hoppers are fed by a 5 hp blower located adjacent to the upstairs hoppers and right above the woodchip storage area. The blower acts like a big vaccuum cleaner by sucking the chips from the storage area and blowing them directly into each hopper as required. Hopper discharge is controlled by a gate valve. When the small boiler hoppers get empty a gate opens on the upstairs hoppers and gravity forces the chips to flow into the lower hopper until it is filled.

Since its implementation the handling system has performed very well. It has significantly reduced the labour required for fillings as well as reduced the time between fillings.

3.3 Heat Distribution Process

Hot water pumped from the sawdust/woodchip boilers to the reserve tank circulates constantly to the existing oil boilers in the

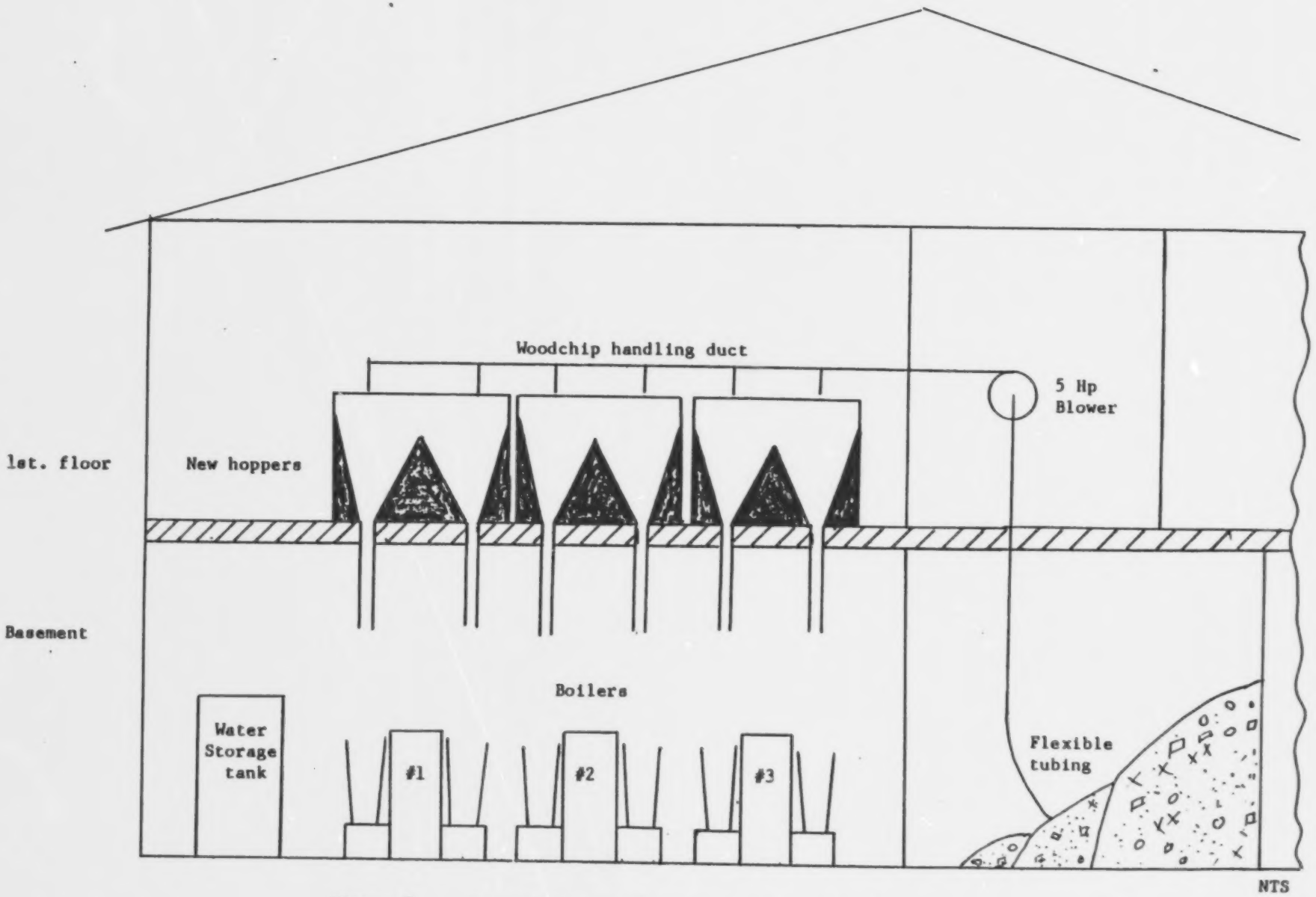

Figure 2 - General layout of boilers and handling system

other buildings. The oil boilers are maintained in a standby mode: at operating water level, temperature and pressure by hot water which circulates to them from the reserve tank. When a thermostat signals for heat in any building the water entering the boiler from the reserve tank is immediately diverted to the radiator system in the building and then returned to the reserve tank in the boiler house for reheating. If a building does not require heat, the hot water circulating from the reserve tank simply flows through the oil boiler and returns to the reserve tank in the boiler house, continuing this cycle until heat is again required by the building. Essentially this is the heat distribution process involved with the energy system. (See Figure 3).

3.4 <u>On Site Construction</u>

Immediately upon notification that the project had been accepted by the Demonstration Program, preparations were rapidly underway to convert the vacant building into a boiler house and fuel storage facility. The rooms of the entire ground floor were dismantled and the basement transformed into a large (17.7m x 10.7m ; 58' x 35') storage area and a separate boiler room. A steel roof was added to the existing shingle roof which had deteriorated. A brick chimney with three (3) 30cm (12") liners was erected outdoors. The converted basement could now accommodate the boilers and the fuel.

Trenches were dug from 1.2m (4') to 2.1m (7') deep to lay the

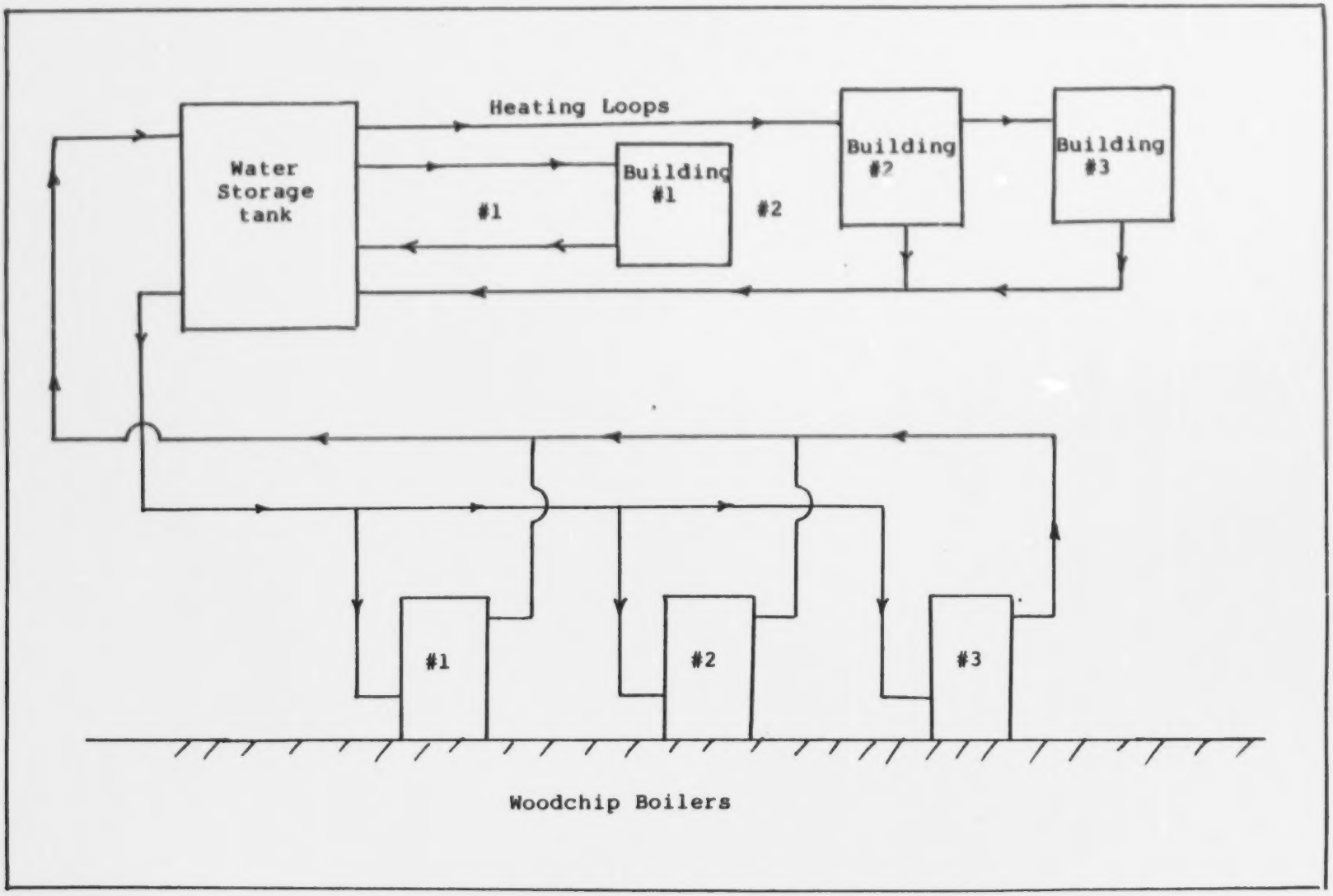

Figure 3 - Schematic of distribution piping

pipes from the boiler house to the three other buildings. Interior plumbing connected the oil boilers to the distribution system.

Understandably, several problems developed during this period of outdoor construction; particularly, considering that the construction began the last week of November of 1982 and went through December 23, 1982. The cold hampered the workers' efficiency. Machinery and general equipment often operated insufficiently. Therefore, careful attention from the operator was required regarding mechanical difficulties created by frost, sleet, water, ice, etc. Frost and rain interfered greatly with the digging of the trenches and laying of the pipes. Water had to be pumped from the trenches before the pipes were laid on fine gravel and then covered with sand and gravel. Fortunately, the cold weather did not interfere with the interior plumbing and general work on the oil boilers which had to be shut down temporarily.

4.0 PERFORMANCE OF SYSTEM

4.1 General

In 1980 Beth Shalom consumed 46,000 l (12,189 imp. gal.) of oil, while in 1981 only 38,000 l (8,359 imp. gal.) were consumed. The 1981 figure reflected the abnormally milder temperatures in the first few months of that year. Incidentally, 1981 was the year oil consumption was at its lowest at Beth Shalom. In 1982, 46,850 liters (10,411 imp.gal.) of oil were required to heat the buildings, and one building - the workshop - closed during January and February to minimize the heating costs. From experience, however, the average oil consumption within the last eight years at Beth Shalom ranges from 50,000 l to 54,550 l (11,000 to 12,000 imp. gal.) annually. At today's price of $1.65 per gallon ($.365/l), this represents an annual sum of $19,800.00 compared to $9,000.00 five years before and $16,500.00 eighteen months ago.

In the winter of 1983 the sawdust/woodchip system began operation. Throughout the late winter and spring of 1983 several problems with the system developed. Reliance on the back-up oil systems was necessary to compensate for the needed heat; thus accounting for the 24,574 liters (5,460 imp.gal.) of oil consumed at a cost of $8,000.00. Considering that the first boiler had been installed during the second week of February, the second boiler during the last days of February and the third one in mid-March, the system did significantly reduce the oil consumption

regardless of the boilers' operating time and the problems encountered in the general functioning of the system. What has been most encouraging since, however, is that from November 12, 1983, no oil has been consumed for the heating needs, which has exceeded our expectations, especially during the intense cold periods.

4.2 Boilers

The objective and aim in installing the system was to reduce our dependency on oil; this objective has definitely been achieved. But this accomplishment results basically from the proper maintenance of the units and the fuel consumed. Other factors contributing to the over-all success of the units required the proper balancing of the sawdust/woodchip system with each individual boiler. Besides, the sawdust/woodchip boilers had to be properly coordinated to function effectively with the oil boilers in the other buildings which were affected by different altitudes causing erratic and sometimes insufficient pressure for maximum heat distribution.

Much performance improvement of the sawdust/woodchip boilers required manual operation of valves and, initially, manual pump control. The operating efficiency of the boilers greatly improved when the circulating pumps on the boilers were converted to be regulated by the aquastats. Coordinating the base compartment with the top part of the boiler increased overall efficiency and performance. These proper adjustments enabled the boilers to remain hot and to supply the reserve tank with hot

water more effectively than when the base and top compartments required manual adjustements.

In operating three boilers constructed by the same manufacturer for two seasons five areas of concern must be noted:

i) coordinating water compartments
ii) instrument placement
iii) interior baffle plate
iv) face plate (cleaning plate)
v) cleaning tubes

4.2 <u>i) Coordinating Water Compartments</u>

The boilers are composed of two different water compartments; the top compartment of the boilers contains approximately 386 l (85 gal) of water, compared to the bottom compartment which contains a maximum of 68 l (15 gal) of water. Both the top and the bottom feed pipes are the same size - 3.2cm (1.25"), and both return pipes are 3.2cm (1.25").

For the boilers to function efficiently, one must coordinate the bottom unit with the top unit. This would require adjusting the bottom return valve to a point where the bottom unit would circulate its hot water content at about the same rate that the top unit circulates its hot water content to gain maximum efficiency. In other words, 68 l (15 gal) of water had to flow out of the bottom unit in about the same period of time that 180 l to 227 l (40 to 50 gal) flowed from the top unit. This required much experimentation with the valves to obtain the proper flow.

ii Instrument Placement

The aquastat and temperature pressure gauges on the boilers do not correspond with one another. On one boiler the instruments are inserted on a slightly vertical plane rather than on the horizontal plane intended for this system. It is most likely that on this boiler the instruments' sensors are in contact with the top steel plate of the boiler or in contact with a nearby smoke pipe; hence, reflecting inaccurate water temperature readings. The readings are determined when the boiler empties its hot water by a thermometer inserted directly into the hot water pipe leading to the reserve tank. (Incidentally, this thermometer operates correctly.) The same instruments on the two other boilers seldom correspond with one another. For example, the aquastat on one boiler can be set for 82 C (180 F) but the boiler discharge temperature is 87 C (188 F). This can be confusing for the inexperienced operator unfamiliar with the system.

iii Interior Plate

The manufacturer had installed a baffle plate to control flue gas flow in the smoke chamber but in so doing, the baffle has contributed much to the creosote creation and low flue temperatures. The time involved for the hot smoke and gases to follow the expected piping cycle caused the smoke and gases to cool and condense into liquid creosote which then flowed from the smoke pipes. The boiler tubes would then cake with the sticky

tar-like substance and soon plug as the ashes clung to this material.

The design was modified by cutting a hole in the plate and attaching a damper-like door or gate which can remain open or closed . With this modification, the tubes have remained clean and the flue reasonably hot; ranging between 95 C and 121 C (195 and 250 F). Before this modification the flue temperatures varied between 29 C and 52 C (85 and 125 F). The operator believes that this baffle-plate could be eliminated entirely without affecting the boiler's performance.

iv Face Plate (Cleaning Plate)

The bolted face plates, which must be removed to clean the interior tubes, have caused some concern. The plates weigh between 13.6 and 18kg (30 and 40 lb) and whenever they are removed the studs wear badly. After sufficient wear the nuts no longer screw on the studs to hold the plate in place. The welded studs cannot be easily replaced when the threads are worn. It is suggested that this could be altered by eliminating the bolts altogether and by installing a set of heavy duty airtight handles and catches to hold the plates in position. This would also save cleaning time and effort for the operator.

V. Cleaning Tubes

Cleaning the interior tubes is facilitated by several special tools; specifically, a long flexible drill shaft with a chuck to

attach a cleaning brush. A variable speed drill would be useful for the cleaning process.

On one of the boilers the entire top must be removed to clean the back tubes. Because the top weighs about 79kg (175 lb) special care must be exercised to prevent personal injury while it is being removed. The two other boilers of slightly different design are cleaned by removing the front and back plates.

The burners and the boilers themselves (with the above exceptions) appear to be of good design with potential for excellent combustion and thermal efficiency. The boilers are compact, noiseless and relatively easily maintained. With proper modifications, the boilers would be a good prototype for replication, production and sales. (See Appendix VI.)

5.0 COST/BENEFIT ANALYSIS

5.1 General

The total capital costs of the Beth Shalom sawdust/woodchip project project is $97,233. Federal and provincial governments contributed $68,500 through the Conservation and Renewable Energy Demonstration Program and Beth Shalom paid $28,733. An estimated additional $12,900 will be required to completely automate the sawdust/woodchip feed system and for needed modifications and repairs of the boilers, buildings, grounds, etc.

5.2 Payback Period

A payback period is calculated by dividing the estimated capital costs by the estimated annual savings.

Capital Costs	$ 97,233
CREDA FUNDING	$ 68,500
PROJECT PROPONENT	$ 28,733
Annual Savings (Avg.)	$ 11,452

$$\text{Payback Period} = \frac{\$\ 97,233}{\$\ 11,452} = 8.5 \text{ Years}$$

Therefore a simple payback of 8.5 years is calculated for this project.

Appendix I and II offer a more detailed account of the cost and savings associated with this project.

6.0 CONCLUSIONS

Economics are the most obvious advantage of having a residual wood fuel system; the savings over oil, gas, or electricity are significant. Another advantage, less obvious to the owner of such a system, but nonetheless as equally important as the first mentioned, is the system's effect upon the local economy. Jobs in both manufacturing and forestry are simultaneously created often times, within the local community.

Environmental and ecological benefits are gained by converting to this renewable source of energy - a product which has been buried and left to rot in sawmill yards for years. Today, new and better means of utilizing this material is economically available and a once neglected renewable resource could now be further developed in both the private and the public sectors of the communities.

7.0 RECOMMENDATIONS

1. The furnace/boiler units should be constructed identically to set specifications. Standardization is necessary for proper operation and maintenance as well as future manufacturing in larger quantities.

2. The bottom water chamber for firebox cooling must be tied in with the main water chamber of the boiler to allow proper circulation of water.

3. The unit should be certified by the Canadian Standards Association when suitable standards have been formulated to simplify obtaining insurance coverage.

4. The chimney should be placed indoors to improve draft characteristics of the combustion system and to help reduce creosote buildup due to low stack temperatures.

5. A service network for these heating systems is needed.

A P P E N D I C E S

APPENDIX I : Cost Analysis

APPENDIX II : Table of Costs

APPENDIX III : Information Transfer

APPENDIX IV : Energy Requirements

APPENDIX V : Fire Safety

APPENDIX VI : Modifications and Repairs

APPENDIX VII : Photographs

APPENDIX I

COST ANALYSIS

List of Expenditures by Item	Total Expenditures Claimed to Date for This Item	Total Expenditures Not Claimed to Date for This Item
Nordic Consultants	$ 6,971.17	$ 130.46
Tilley Manufacturing	15,647.50	44.00
James A. Dionne	35.00	--
Gaetan Michaud Plbg.	11,150.58	6,204.63
Edmundston Industries	8,170.02	--
Day & Ross Ltd.	725.68	--
Guilford'Ltd.	8,544.63	--
Grand Falls Milling	2,010.00	--
R. Gallup	60.00	--
Wright & Everett Co.	6,000.00	--
United Bldg. Supplies	51.03	--
Alb. Dionne Welding	160.00	--
Bldg. Renovation	7,525.00	--
Truck Rental	1,575.00	--
Pipe Installation	5,396.00	--
Maintenance Man	1,147.60	--
Project Manager	2,313.75	--
Metro Heat	333.07	84.98
Victoria Mach. Shop	807.73	--
Marc C. Johnson	145.00	--
Humphrey Transfer	19.05	--
Edgar Electric	1,600.21	158.47
Wright & Everett	3,700.51	--
Metro Heat	911.47	27.06
Dan Goodwin	--	19.50
Linton/MacDonald	--	1,008.00
Canada Blower	--	2,215.00
ABM Machine Shop	--	2,260.95
TOTALS	$85,000.00	$12,233.05

APPENDIX II

TABLE OF COSTS
(Approximation)

DESCRIPTION	1983	1984	1985	1986
1. Oil used (without wood units)	12,000 gal.	12,000 gal.	12,000 gal.	12,000 gal.
2. Predicted Costs $1.77/gal.*	$21,240.00	$23,280.00	$25,560.00	$28,080.00
3. Heating oil consumed once energy system installed	5,460 gal.	1,200 gal.	1,200 gal.	1,200 gal.
4. Reduction in heating oil	6,540 gal.	10,800 gal.	10,800 gal	10,800 gal.
5. Reduction in cost	$11,576.00	$20,952.00	$23,004.00	$25,272.00
6. Operating cost of new system:				
$/ton sawdust	28.00	31.36	35.12	39.33
$/ton woodchips	45.00	50.40	56.45	63.22
7. No. of tons required to replace heating oil:				
- sawdust	125	175	175	175
- woodchips	5	75	75	75
8. Renewable energy costs:				
Operating cost sawdust	$ 3,500.00	$ 5,488.00	$ 6,146.00	$ 6,882.00
Operating cost woodchips	225.00	3,780.00	4,233.00	4,741.00
TOTAL COSTS	$ 3,725.00	$ 9,268.00	$10,379.00	$11,623.00
ESTIMATED ANNUAL SAVING (5-8)	$ 7,851.00	$11,684.00	$12,625.00	$13,649.00
AVERAGE ANNUAL SAVING	$11,452			

* Price as of March 1985
- Assume 10% increase in oil cost per year

APPENDIX III

INFORMATION TRANSFER

Numerous visitors have come to see our sawdust/woodchip system. They asked questions pertaining to the safety of the system and to its economic value. I would refer the visitors to the manufacturer regarding the safety features of his individual boilers, stating that these boilers were under extensive observation and that I could not explain these features in detail. I emphasized their economy and also stressed the other advantages of burning residual woodwaste fuel which I have mentioned earlier in this report.

Several visitors have converted to burning woodwaste fuels since their visit to Beth Shalom. They either constructed or modified their own systems or inquired with the manufacturer for a boiler suitable for their needs. Much interest has been manifested by the public for this type of system; particularly when they realize the general advantages of this system over heating oil or electricity.

Of the many visitors who came, several desired to implement a similar system in different type buildings. For example, one visitor, an administrator, considered its possible use for a hospital; another, a proprietor, for his apartment buildings; and still another, a clergyman, for his church. Engineers from a large company visited the site with Mr. Goodine for the possibility of installing the system in greenhouses.

Briefly, much information about our system has been publicized by the visitors themselves who encourage others to visit the project at Beth Shalom.

APPENDIX IV

ENERGY REQUIREMENTS

A study done in August 1982 by Nordic Consultants of Edmundston determined that approximately 900,000 BTU/H would be required to properly heat the buildings. Our tentative system would require this minimum capacity to achieve our goals of reducing our oil consumption; thus the manufacturer was required to construct his units large enough to produce the needed heat.

Since November 12, 1983 until today, our sawdust/woodchip system has consumed approximately 229 tonnes (225 tons) of fuel - the fuel being composed of three parts sawdust to one part chips. All of the fuel was placed in storage during November and December and the fuel came directly from the sawmill as the logs were being sawed and chipped; consequently, the moisture content of the fuel was high and remained relatively high throughout its storage and consumption time.

For specific conversion factors and data, none are presently available comparing the fuel consumption and energy output to that of its oil equivalent. However, as I have frequently reiterated throughout my report, no oil has been consumed to heat the buildings during this period; but perhaps with drier fuel, less would be required to achieve similar results. It had been estimated that if the moisture content of the fuel had been about 20%, a maximum of 137 tonnes (135 tons) of fuel would have replaced the 59,550 l (12,000 gal) of oil.

APPENDIX V

FIRE SAFETY

One of the questions most frequently asked concerned the safety of the system in general. Regarding the safety factors of the boilers themselves, I would recommend to my visitors that they consult with the manufacturer for details .

A recurring question pertained to the fire backing up in the hoppers. Regarding this question I assured my visitors that I have never experienced this particular problem and that I considered the possibility remote. I have heard of this happening in similar systems but when I inquired further about the fires, they seemed to have occurred only after the boiler or furnace had been shut down for several days or weeks with fuel still remaining in the hoppers. I explained that if a boiler were to be closed down, no fuel should remain in the hoppers, to prevent burnback.

In those events of electrical failures, the boilers are generally safe since all drafts close automatically, thus, preventing the fire from burning intensely enough to either cause boiling of the water or rupturing of the units. The fire in the combustion chamber would eventually extinguish itself by consuming the available oxygen necessary for the fire to continue to burn significantly. Even in these cases of electrical failures, the fire does not back up in the hoppers; for this to happen, it is my knowledge that the boilers would have to be shut down for

several days with fuel remaining in the hoppers. Incidentally, the pressure relief valve on the top of the boiler would release excessively hot water before any damage would ensue.

APPENDIX VI

MODIFICATIONS AND REPAIRS

For the safe and proper operation of the boilers, two major changes became necessary.

Major repairs were done last August when the entire exterior plumbing of all three units had to be redone. (The plumbing on the units had been done by the manufacturer himself.) In April of 1983 a valve on one boiler feed pipes ruptured and seriously burned the operator nearby who had been filling a hopper with fuel. After investigating, it was found that some materials used in the installation were of type not generally used in a heating system with characteristics as described in this report.

The plumbing was redone after having consulting with the plumber and the project engineer. Since then, the plumbing has remained intact and affords security and safety to the operator.

The second major change in the system was coordinating the bottom water compartment with the top one. This change involved the installation of an aquastat, thermometer-pressure guage, and a pressure relief valve to the base water compartment. A 1.27cm (0.5") pipe from the feed of the base is connected to the bottom of the top water compartment.

The return line connects the bottom of the top water compartment to the bottom of the base compartment. A Grundfos pump on the 1.27cm (0.5") feed line, governed by the base aquastat, pumps the

base hot water into the top compartment at regular intervals until the boiler's top aquastat activates the boiler's main pump for emptying.

Having the two water compartments interconnected assures the operator of the security of the system and relieves the operator of manually controlling boiler operation. The problem of water boiling in the base compartment has thus been eliminated and the boilers can now be fired by most anyone without excessive training in the proper operating procedures.

APPENDIX VII

Photographs

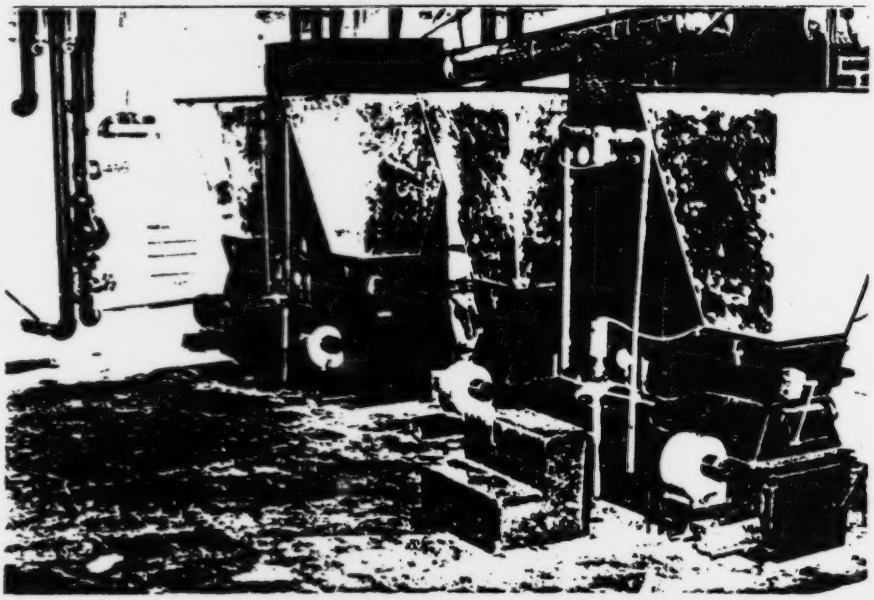

Photo 1 - Two Woodchip Boilers and Hot Water Storage Tank

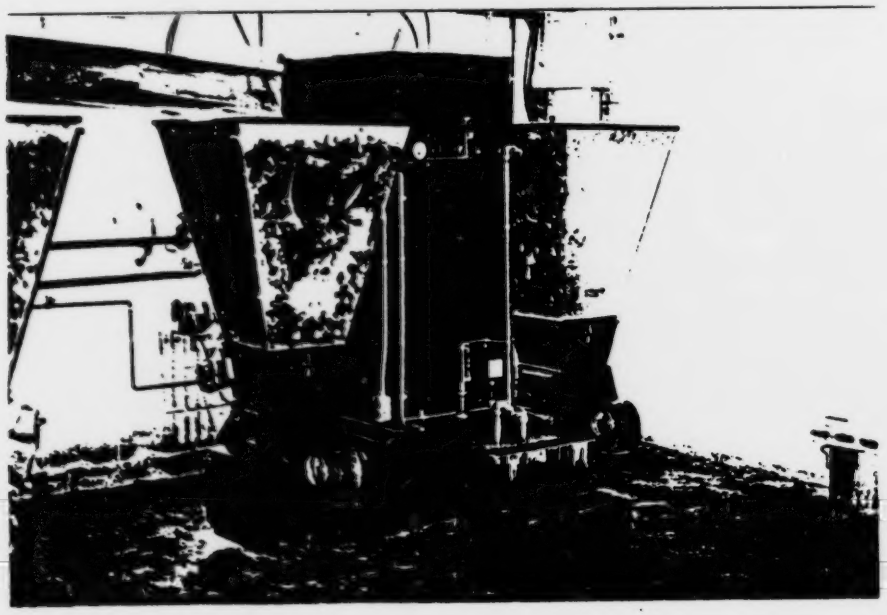

Photo 2 - Individual Woodchip Boiler

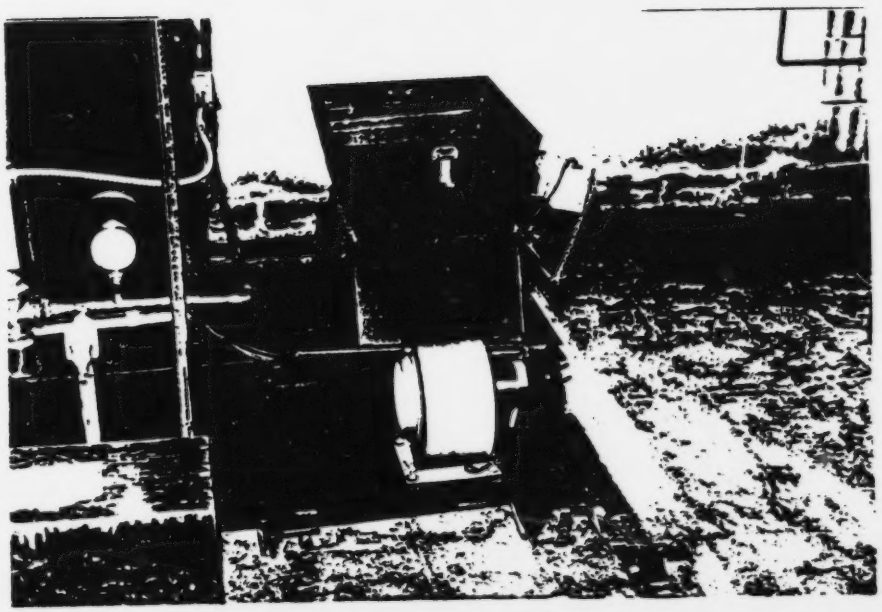

Photo 3 - Woodchip Boiler with RH hopper removed

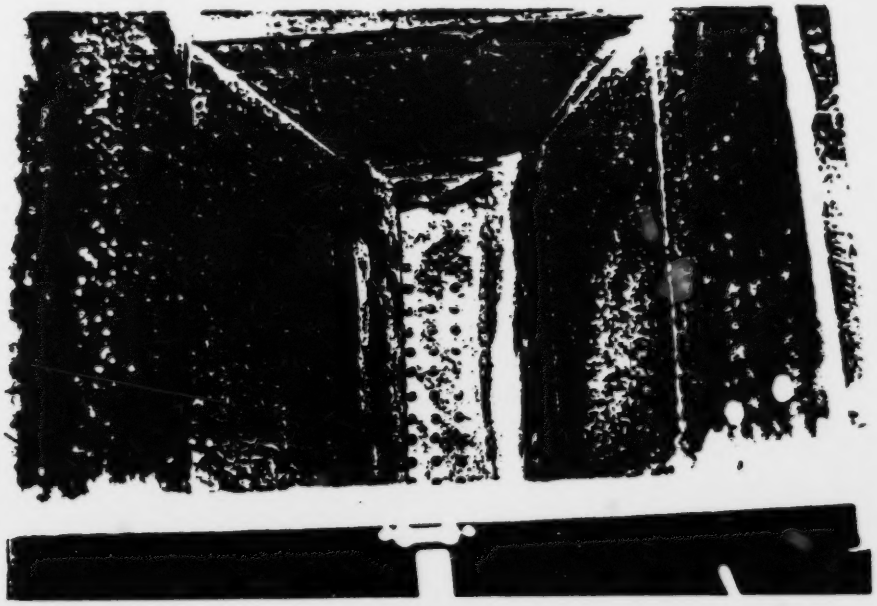

Photo 4 - Combustion Grate as seen by looking down into the hopper

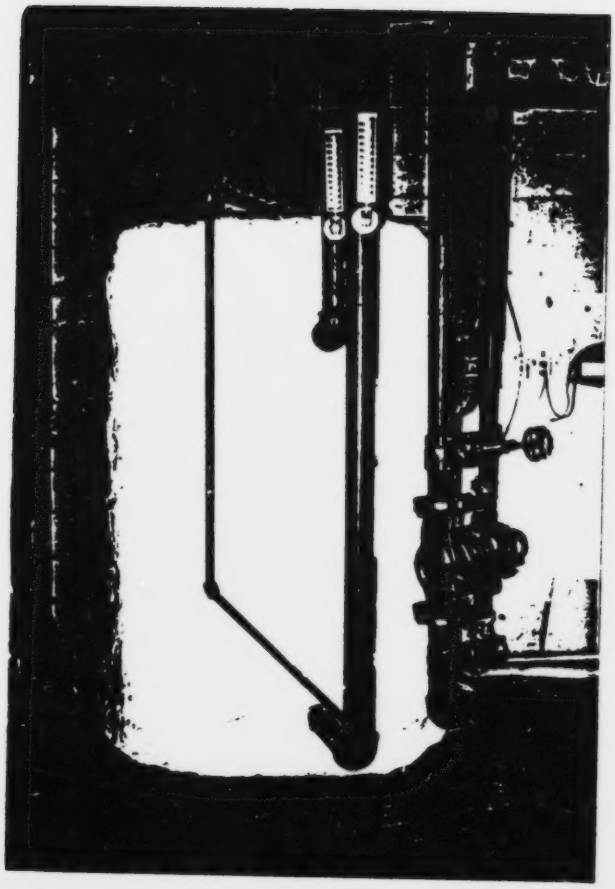

Photo 5 - Hot Water Storage Tank